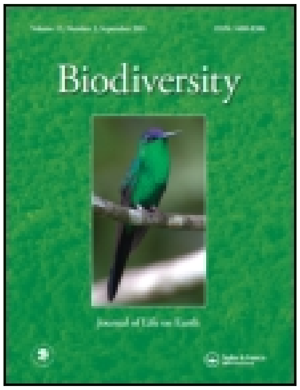

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The Himalayas of India: A treasury of medicinal plants under siege

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The Himalayas of India: A treasury of medicinal plants under siege

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Abstract. *Wild plant raw material is in great demand around the world for use by pharmaceutical companies, ethnomedicinal practitioners, and a variety of traditional medicines. India is one of the world's major exporters of raw herbal drugs and the Himalayas are renowned for their vast storehouse of medicinal plants. The domestic and international demand is met mainly through unsustainable in-situ harvesting which has become a major threat to the survival of many Himalayan plant species. Additional conservation initiatives are urgently required as well as more research on the cultivation of wild Himalayan taxa. This study reviews the biodiversity of the Indian Himalayan region as a whole, the specific effects of climate, geography and anthropogenic activities on the endangered and threatened species, with particular reference to the Himachal Region. An assessment has been given of the highlights and shortcomings of current conservation initiatives.*

INTRODUCTION

It is estimated that close to 15 % of the approximately 70,000 known plant species have medicinal properties which means that over 10,000 plant species are used in medicine at one time or another (Chevallier 1996). Over 5700 plant-based traditional medicines are listed in the Chinese *Pharmacopoeia*. On average, 50 % of the plant species of any ecosystem in India are used by various communities in ethnomedicine. The tribal people use over 7500 plant species in primary health care and over 2000 species are also used in the Indian traditional system of medicine. India possesses vast cultural and geographical diversity and the communities of each region offer their own unique way of practising indigenous medicine. There are over 460,000 medicinal practitioners in India, including 30,456 institutionally trained "professionals" (Bajaj and Williams 1995).

A large quantity of raw, wild plant material is used by pharmaceutical companies all over the world and there has been an unprecedented global increase in the use of herbal medicine since 1980. Consequently, many plants have come under close scrutiny for the presence of active medicinal components (Aryal 1993). In recent years, India has been ranked as the second largest volume exporter of raw herbal drugs, following the lead of China (Lange 1997). The demand for medicinal plants, whether for the domestic sector or for international export, is met mainly through in-situ harvesting. This has resulted in overharvesting, one of the biggest threats to the important medicinal plant species in the Himalayas. Conservation initiatives to remedy this situation are urgently required as there is still a paucity of research to show the potential of the natural Himalayan habitats in terms of medicinal plant production. More information is required on the biology, adaptation mechanisms, and habitat ecology of the majority of threatened trade taxa as well as field-based demonstrative agro-technology for the various agro-climatic zones in the Himalaya.

Various studies indicate that the availability of information on medicinal plants of the Himalayan Region is meagre and mainly restricted to inventory. Dhar et al. (2000) noted that 50% of the contributions focussed on distribution and availability, 16.3% on status (21% on population studies, 79% general), 24.4% on cultivation and propagation, 4.7% on extraction and trade and 4.7% on conservation. This lack of information hinders

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Stephen Aitken is a biologist, writer and illustrator. In addition to his position as Managing Editor of *Biodiversity* and International Coordinator of *Tropical Conservancy*, his books, articles and poems have been published in Canada, Switzerland, Norway, the United States and Britain.

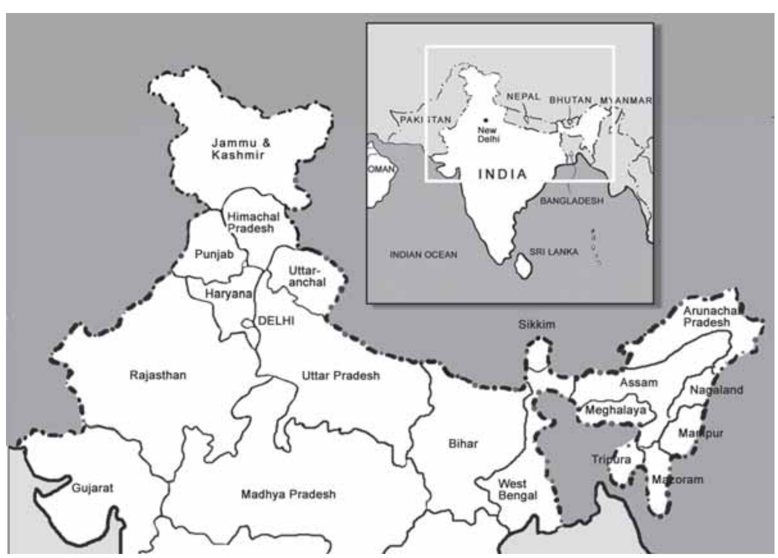


Figure 1.
Map of India and states

Figure 2. A characteristic high altitude conifer forest of Himachal Pradesh. (All photographs in this article copyright of Dr. Hemant Badola).

researchers and natural resource managers in making adequate judgements of the quantitative harvesting of medicinal plants from the wild. Location-specific data covering different climatic and geographical regions of the Himalaya is vital to pinpoint the relative threats to natural populations of taxa, particularly those considered threatened (Badola and Pal 2002, 2003).

This paper investigates the status of medicinal plant biodiversity, particularly the threatened species of the Indian Himalayan Region with special reference to the state of Himachal Pradesh. It discusses the specific effects of climate, geography and human activity on medicinal plants. Furthermore, it highlights the success and constraints of the various conservation initiatives.

TARGET AREA

The Himalayas are among the youngest and most unstable mountain ranges in the world. They isolate the Indian subcontinent securely from the rest of Eurasia. The summer monsoon determines the pattern of rainfall, which amounts to more than 2500 mm annually on the outer ranges (Singh and Singh 1987), with the amount decreasing from east to west. These mountains separate the monsoon climate of south Asia from the dry and cold climate of central Asia.

The 2400 km long and 300 to 400 km wide Indian Himalayan Region (IHR) comprises five major biogeographical zones (see Fig. 3). The IHR has an altitudinal range of 300 to 8000 m and the recorded forest cover varies from 9.08% (Jammu & Kashmir) to 67% (Uttaranchal).

Figure 3. The biogeographical zones of the Indian Himalayan Region (*based on*: Dhar and Samant 1993).

The primary region of concern for this article, Himachal Pradesh (HP) in the northwest Himalayas has an area of 55,673 km^2 and covers 1.69 % of the country, 9.42 % of the IHR. HP has an international border at its northern and north-eastern extremities. In the west it meets with the plains of Punjab, in the south with Haryana, with Uttaranchal on the southeast, and with the mountains of Jammu & Kashmir (J&K) to the north. HP offers a range of climates and forest types from subtropical to alpine. The average rainfall varies considerably from 1800 mm in the mid-hills to less than 200 mm in the cold dry zone. Over 34% of its geographical area rises above 4000 m. The entire state is divided into twelve administrative districts.

Indian Remote Sensing data (IRS 1C/1D WiFS) recently assessed the forest cover of HP as 17.15% of the state area (Joshi et al. 2001). These forests can be described as temperate conifer, mixed (Himalaya moist and dry temperate), sub-alpine, subtropical (subtropical moist deciduous, swamp and subtropical pine) and broad-leaved (tropical dry deciduous and subtropical dry evergreen). The majority of the population in the state earns its livelihood through agriculture and horticulture with major crops including wheat, maize, and rice as well as subsidiary crops of gram, buckwheat, lentils, sorghum, and potatoes. Apples have become an important cash crop in the last couple of decades.

HIMALAYAN FOREST BIODIVERSITY: A BRIEF OVERVIEW

Flora: The Himalayas are rich in biodiversity due to the variety of habitats available. This is evidenced by the presence of 21 vegetation types, 10 forest types and 11 forest formations, as reviewed by Dhar (2002). Broadly speaking, the Himalayan mountains, encompassing Afghanistan, Pakistan, India, Nepal, Tibet, Bhutan, north Myanmar and southwest China have about 70% endemism. India as a whole possesses a rich floristic diversity (17,000 species of flowering plants) with 33.5% endemism (Nayar 1996). Out of the total number of endemics reported for India, about 46% are found in the Indian Himalaya. About 3471 endemic species of flowering plants are reported in the Himalaya. Singh and Hajra (1996) reviewed the availability of about 8000 species of angiosperms (40% endemic), 44 species of gymnosperms (15.91% endemic), 600 species of pteriodophytes (ferns) (25% endemic), 1737 species of Bryophytes (32.53% endemic), 1159 species of lichens (11.22% endemic) and 6900 species of fungi (27.39% endemic). Berberidaceae, Saxifragaceae, Ranunculaceae, Rosaceae and Umbelliferae are some of the leading Himalayan families with a high degree of endemism, i.e. 98.7%, 92.3%, 72.7%, 70.4% and 68.8%, respectively. Of a total of 111 monotypic genera, 68 are confined to the Himalayas, in most cases the Himalayan endemic plant diversity is greater than that of the adjacent mountain regions (Dhar 2002).

The north western (mainly HP) and western Himalayas exhibit dense tropical forests in the warm, lowland Bhabhar and Siwalik hills, deciduous mixed forests in the middle mountains, and scattered arctic-type and alpine vegetation at higher altitudes (see Figure3). The Lesser Himalaya (lower altitudes) supports luxuriant trees of *Pinus roxburghii* and *Alnus nitida* on the slopes devoid of good soil while the moist rich slopes are occupied by *Alnus nepalensis, Quercus leucotrichophora, Rhododendron arboreum*, etc. The forests of *Q. semecarpifolia, Q. floribunda*, and *Pinus wallichiana* are characteristic of the higher altitude zones of the Lesser Himalaya. The dominant species *Abies sp., Betula utilis, R. campanulatum*, and *Juniperus communis* represent the forests of the Great Himalayan range. The higher altitudes beyond the tree line (above 3600 m) provide a rich assemblage of herbs in the alpine meadows and grasslands (Figure 2). The various species of herbs of the genera *Aconitum, Arnebia, Picrorhiza, Rheum*, and *Meconopsis* and the scrubs *Rhododendron anthopogon* and *R. lepidotum* are some of the important plants of these heights. In Uttaranchal, Sal (*Shorea robusta*) and Oak (*Quercus spp.*) forests form climax communities, representing warmer and cooler climates, respectively, along 300-2500 m transects (Singh and Singh 1987). However, old-growth climax forests are being replaced by even-aged successional *Pinus roxburghii* forests. This is further reflected by the low availability of *S. robusta* and *Quercus spp.* seedlings over most areas.

The Eastern Himalayan ranges are known for their high number of endemic taxa (1808 vs 1195 in the western sector). The large canopy broad leaf forests growing in the eastern sub-montane belts (<1000 m) are comparable to typical tropical rain forests.

Shorea sp. is the dominant component of tropical low altitude deciduous forests (below 800 m). The sub-tropical zone (800-1800 m) is dominated by *Schima-Castanopsis* and *Pinus sp.* forests in association with *Alnus nepalensis* and *Rhus javanica*. The higher ranges (1800-3000 m) provide broad-leaved forest combinations of *Quercus-Mechelia-Acer, Rhododendron-Quercus-Magnolia* and *Tsuga dumosa-Quercus sp.* Between 2800 and 4000 m there are good forests of temperate and sub-alpine conifers, predominantly Fir (*Abies*), Pine (*Pinus*), and Yew (*Taxus*) in the lower belts and Fir, Juniper (*Juniperus*), Larch (*Larix*), Spruce, (*Picea*) and Hemlock (*Tsuga*) in the higher belts. There is a dominance of *Abies densa* forests found at 3000-4000 m. On slightly higher slopes at 4000-5500 m there are patches of *Rhododendron anthopogon* and *Delphinium sp.* grows abundantly. It is interesting to note that tree ferns are mostly reported from the eastern Himalayan region (where epiphytes are also found in abundance) that become rarer towards the north western Himalaya.

Figure 4 (top).
A tree-line meadow of West Himalaya showing *Rhododendron campanulatum* patches along the gullies (to the left).

Figure 5 (bottom).
An alpine pasture (altitude ~4000 m) of North West Himalaya.

Fauna: Protected areas of the Himalayan ranges have been marked out either as biosphere reserves, national parks, or wildlife sanctuaries. Most of these areas earned their protected status decades ago primarily due to their potential for game-hunting. Gradually, with the advent of modern conservation management, the focus has switched to wildlife conservation. For the past several years medicinal plants, as well as fauna and habitat conservation, have become vital components in protected area management planning.

Mammals and pheasants have been given major attention in conservation management. The Manas Biosphere Reserve (MBR) alone harbours 59 mammal species. The Great Himalayan National Park (GHNP) and Kanawar Wildlife Sanctuary (KWLS) in HP harbour large mammals, including carnivores (eg. Black Bears & Leopards), small mammals (eg.Yellow-Throated Marten), ungulates (Musk Deer, Himalayan Thar and Goral), primates (Rhesus and Langur), and large rodents such as the giant Indian Flying Squirrel. Many of the protected areas are known for their key taxa such as the great Indian One-Horned Rhinoceros (*Rhinoceros unicornis*) in the Manas and Bibru Saikhowa Biosphere

Figure 6.
A Monal Pheasant showing off its crown feathers.

Reserves in Assam, the Snow Leopard (*Panthera uncia*) in GHNP and Nanda Devi Biosphere Reserve (Uttaranchal), and the Himalayan Thar (*Hemitragus jemlahicus*) in GHNP and KWLS. Several mammals are listed in CITES and/or Schedule I of the Indian Wildlife Protection Act (1972), such as the Himalayan Black Bear (*Selenarctos tibethanus*), Brown Bear (*Ursus arctos*), Musk Deer (*Moschus moschiferus*), and the Red Panda (*Ailurus fulgens*). The Western Tragopan (*Tragopan melanocephalus*), known locally as "Jijurana", according to popular folk-lore contains the entire spectrum of colours on earth. This endangered pheasant has a marked presence in the GHNP of HP. Similarly, the state bird of HP, the Monal Pheasant (*Lophophorus impejanus*) (Figure 13) with its beautifully coloured male is found widely in GHNP and KWLS (Badola 1998). Its plumage is used by villagers to decorate caps, worn particularly during religious ceremonies in the Kullu valley of Himachal. Endangered reptiles include the common Indian monitor (*Varanus bengalensis*) and the Indian Rock Python (*Python molurus*).

MEDICINAL PLANT BIODIVERSITY

The treasury of diverse medicinal plants available in the Himalayas has been recorded in ancient Indian scripts as far back as 1000 BC. In the IHR, there are over 1748 plant species; (1685 – angiosperms, 12 – gymnosperms and 51 – pteridophytes), including 1020 herbs, 335 shrubs and 330 trees of medicinal value (Samant *et al.*, 1998).

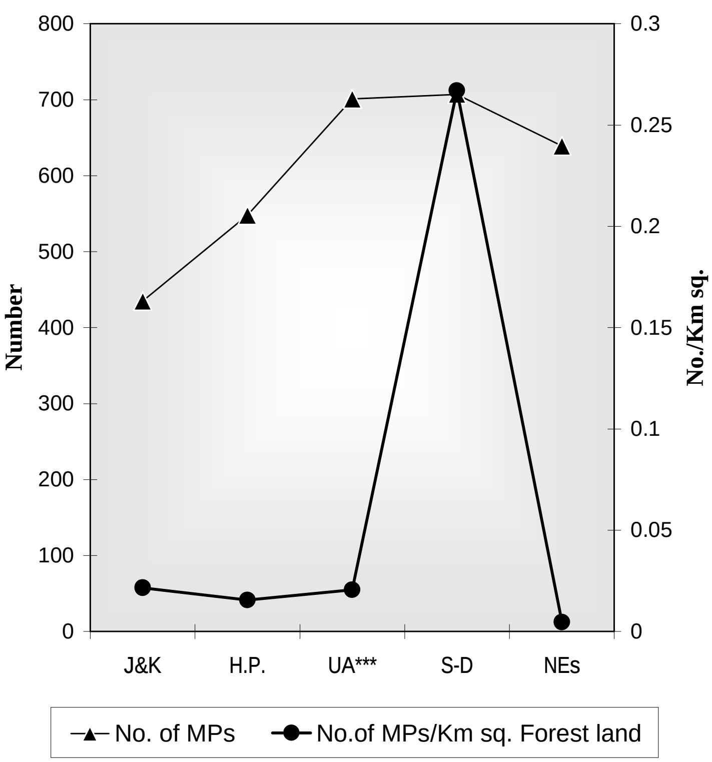


Figure 7.
Medicinal plant species diversity and its ratio with forest cover for different geographical regions of the Indian Himalaya.

A high nativity of 31%, endemism of 15.5% and threatened status (14% of total Red Data plant species of IHR) manifest the region's unique and sensitive medicinal plant diversity. Out of the above 1748 medicinal plants, about 548 species are identified in HP (though estimates range as high as 1000 to 1200 species), compared with 707 in Sikkim and Darjeeling and 701 in the Uttaranchal states (Figure 7). The number of species, in proportion to geographical area of the state, is highest for Sikkim & Darjeeling at 0.0996, while in HP it is 0.0098. The number of medicinal plant species per km^2 of forestland coverage is also highest for Sikkim and Darjeeling at 0.267 and fourth in H.P. at 0.0155 (see Chart 1). Nayar (1996) has listed 6 species out of 78 endemics in Meghalaya State, 8 out of 74 endemics in Manipur-Nagaland and 7 out of 114 endemics in Arunachal Pradesh (in north-east states); 51 (of 569 endemics) in Sikkim (including Darjeeling Himalaya), 16 of 116 endemics in Uttaranchal, 4 of 15 endemics in Himachal Pradesh and 11 of approximately 314 endemics in Jammu & Kashmir.

The literature cites over 45 medicinal plant taxa recorded throughout the IHR. These include; *Acorus calamus* (Bach), *Artemisia nilagarica*, *Bergenia ciliata* (see Figure 6) (Pashanbhed; near endemic), *Cannabis sativa* (Bhang), *Celastrus paniculatus* (Mal-kangani), *Centella asistica* (Brahmi), *Chenopodium album* (Bethu), *Cinnamomum tamala* (Tejpatra; near endemic), *Dactylorhiza hatagirea* (Panja; near endemic), *Dioscorea bulbifera* (Barahi), *Gloriosa superba* (Kalihari), *Hedychium spicatum* (Banhaldi or Kapurkachri; near endemic), *Juglans regia* (Walnut; near endemic), *Litsea glutinosa*, *Papaver somniferum* (Post), *Picrorhiza kurrooa* (Karu), *Rumex nepalensis*, *Solanum nigrum* (Makoi), *Taraxacum officinale* (Dudhi), *Urtica dioica* (Stinging nettle) and *Zanthoxylum armatum* (Timru). An analysis of 360 medicinal plant species of HP showed 18% trees, 21% shrubs, 55% herbs, and 6% others (climbers, a fern and a mushroom) (Badola 2001). This coincides with the Indian Himalaya as a whole, with a breakdown of 19% trees, 19% shrubs, 58% herb species and the remainder Pteridophytes (ferns).

Protected areas such as national parks and biosphere reserves are an in-situ opportunity to conserve representative ecosystems and to focus on the sustainable management of threatened species. The availability of 327 important medicinal plants of Himachal Himalaya has been reviewed for 3 unique high altitude areas; the Great Himalayan National Park (GHNP) (192 species), Lahaul-Spiti (L-S) a suggested site for Biosphere Cold-desert (213 species), and Nanda Devi Biosphere Reserve (NDBR) (95 species) in Uttaranchal Himalaya. There are 39 species common to all 3 areas with the 2000-3000 m altitudinal zone offering suitable habitat to about 56% of the species. A similar trend is also seen for the herb, shrub and tree species (Figure 8) . Some representative species of this

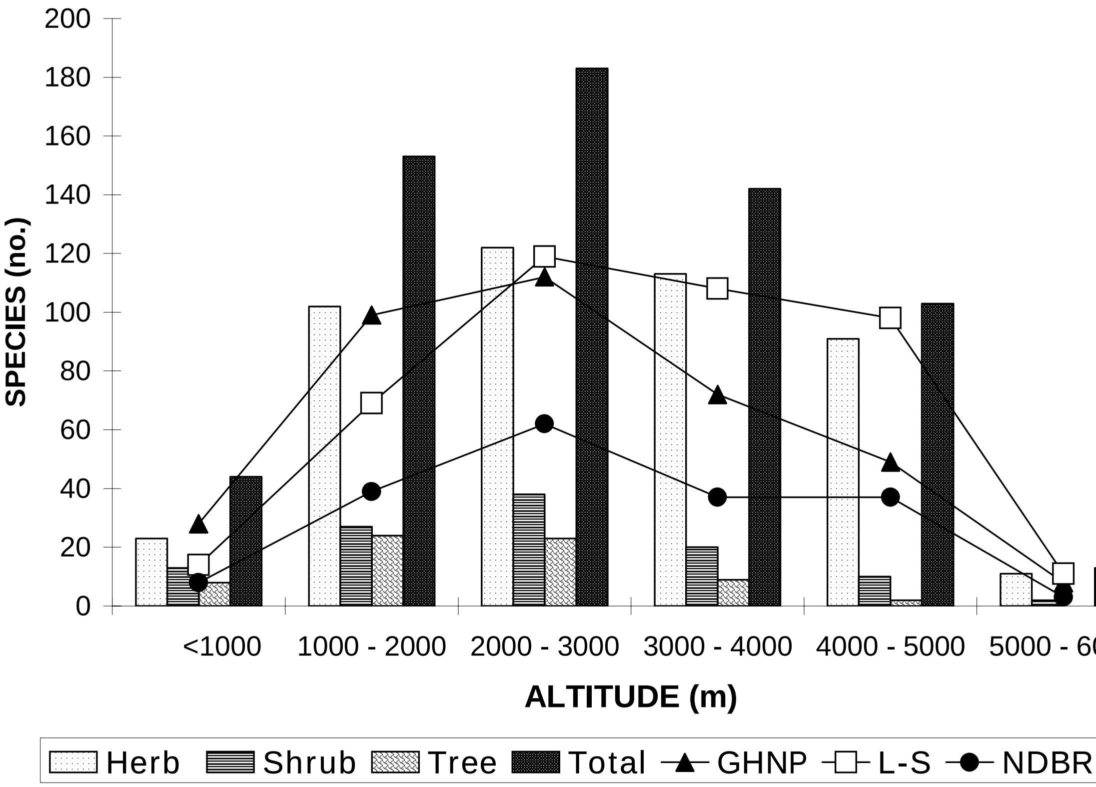


Figure 8. Distribution of medicinal plants, common among Great Himalayan National Park (GHNP) (species based on Singh and Rawat 2000), H.P.; Nanda Devi Biosphere Reserve (NDBR) (species based on Joshi et al. 1999), UA; and Cold Desert H.P. (species based on, Aswal and Mehrotra 1994), along altitudinal zones.

zone are; *Aconitum heterophyllum* (Patish or Aconite), *Angelica glauca* (Chora), *Berberis aristata* (Kashmal), *Gentiana kurrooa* (Kadu), *Hedychium spicatum*, *Heracleum candicans* (Patrala), *Podophyllum hexandrum* (Himalayan Mayapple, Bankakri), and *Valeriana jatamansi* (Nihanu or Mushakbala). Only about 4 % of the species, such as *Delphinium brunonianum* (Laskar), *Lapidium capitatum*, *Ranunculus hyrtellus* (Sarsaupatal), and *Saussurea bracteata* are adapted to altitudes beyond 5000m.

EFFECTS OF GEOGRAPHY, HABITAT AND CLIMATE

The distribution and growth of medicinal plants are

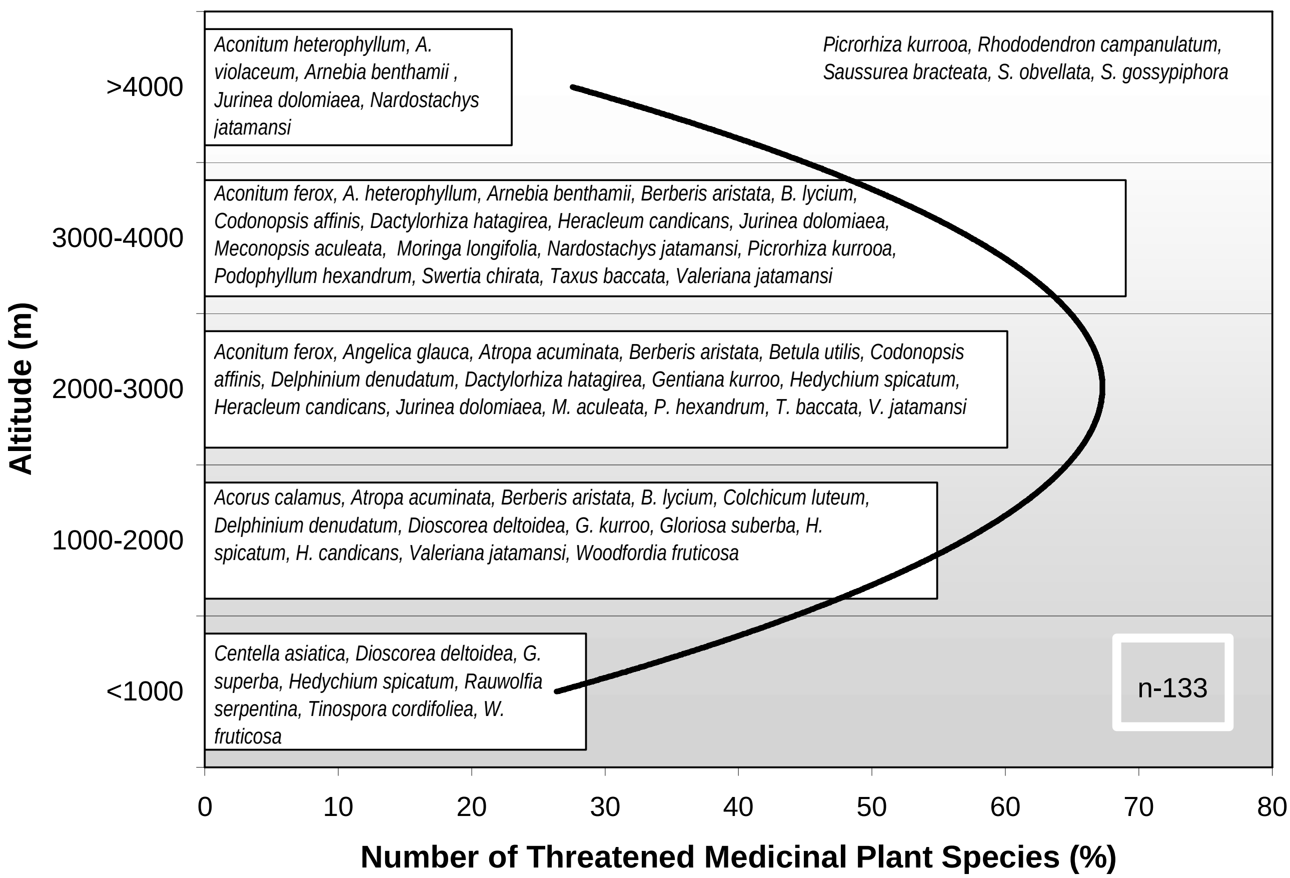
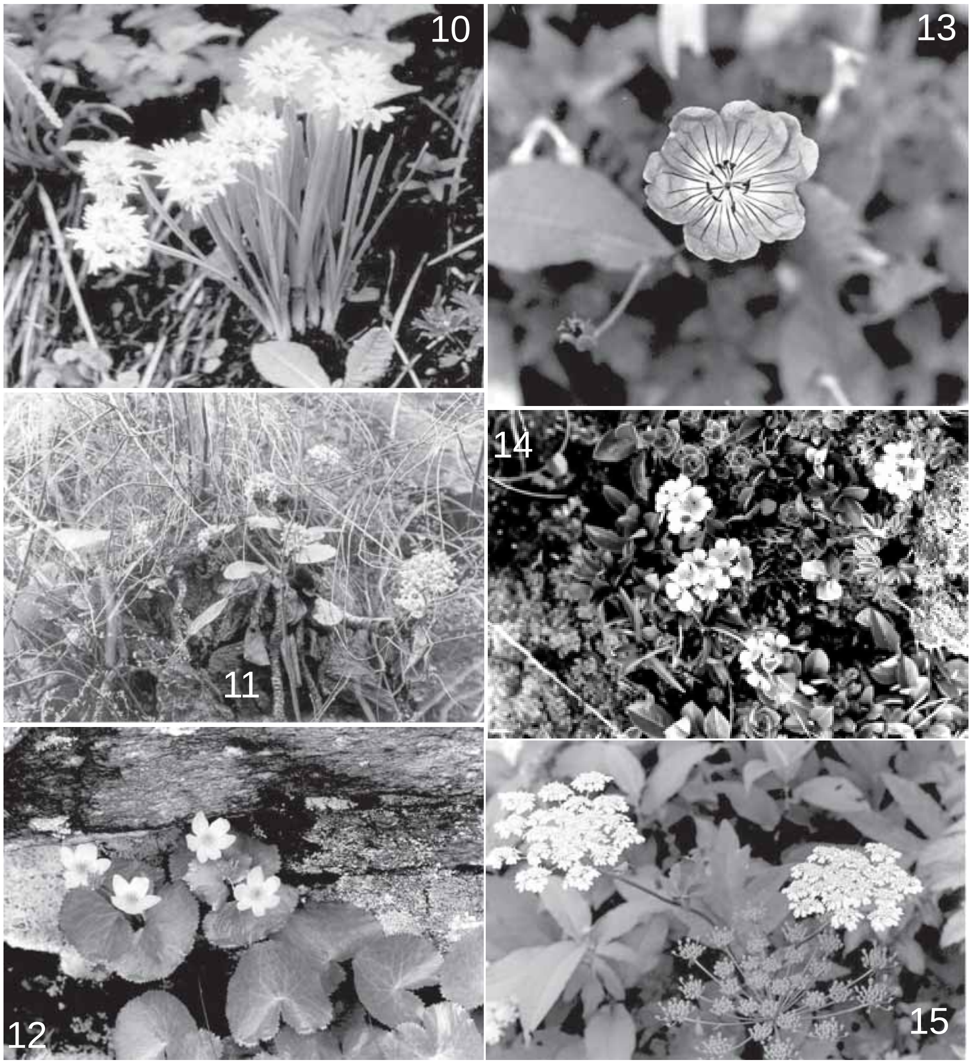


Figure 9. Distribution of threatened medicinal plant species of Himachal Pradesh.



Figures 10-16.
10, *Allium humile* in flower;
11, *Bergenia ciliata* flowering in its typical rocky habitat;
12, *Caltha palustris*, a characteristic plant of high altitude meadows; blooming in moist rocky terrain;
13, A close-up of the enchanting *Geranium wallichianum* flower;
14, High-altitude *Primula rosea* in bloom;
15, *Heracleum candicans* of HP,
16, An endangered Himalayan Blue Poppy (*Meconopsis aculeata*).

directly related to the specific climate and geography of their respective ecological niches. For the herbs, such specificity of the microhabitat often becomes the limiting factor in their distribution, availability and population size. The more specific the climatic and habitat requirement, the more restricted becomes the species distribution, either along altitudinal or latitudinal lines. Widely distributed taxa have relatively more resistance to changing environmental conditions, while species of narrow distribution are highly susceptible to climate change and habitat alteration. In most of the mountain ecosystems, in order to withstand the local climatic conditions, endemic plants often occupy rocky cliffs and drier habitats. Such affiliation is more common in alpine taxa (Dhar 2002).

The climate of any ecosystem is not merely the result of its latitude and longitude, but is also due to the altitude which governs the micro-climate. In HP the altitudinal range of 1000-3000 m provides the most suitable habitats for medicinal plants such as *Centella asiatica*, *Dioscorea deltoidea*, *Jurinea dolomiaea*, *Podophyllum hexandrum*, *Taxus baccata*, and *Valeriana jatamansi*. To be more specific, the 1500-2000 m (305 species) and 2500-3000 m (297 species) range are the richest reservoirs (Badola 2001) (Figure 9).

A declining trend above 5000 m reflects the snowy, severe climatic conditions and the shorter growing period of high altitudes. Most of the Himalayan trade taxa of medicinal value grow naturally in high altitude zones; however, the severe climate of the higher altitudes affects the plants reproductive methods, specifically the flower and seed yields. To safeguard progeny high altitude medicinal plants adopt various vegetative means of multiplication. These means include: the below ground rhizomatous structures of medicinal forbs like *Angelica glauca*, *Arctium lappa* (Burdock), *Megacarpaea polyandra*, *Rheum* (Rhubarb), and *Saussurea*, the production of stolons, as in *P. kurrooa*, *Gentiana sp*., and *V. jatamansi*, the formation of separate fragments of the genets through slow centrifugal spread in herbaceous rosettes, and the root tubers of Aconites. The ramets are attached with stolons and/or runners developed above or below ground and rhizome clusters later produce free individuals. These mechanisms need the support of undisturbed soil surfaces and space to spread. The fragmentation of habitats has proven fatal to the natural regeneration of species in numerous locations in the Himalayas. Excessive uprooting of the underground parts of *A. glauca*, *A. heterophyllum*, *P. kurrooa*, and *P. hexandrum* in the wild has eclipsed their life support systems and has resulted in population loss in the Mari-Rohtang mountains of Manali-Kullu (HP) and in several locations in upper Parvati valley, Kullu (HP). Knowledge of the adaptive mechanisms of threatened medicinal plants is very important for both in-situ and ex-situ conservation research programmes. This knowledge is crucial when attempting a large scale cultivation programme to meet the bulk demand of pharmaceutical companies, because growing plants within their suitable agro-climatic environment not only helps in producing higher yields but also high levels of active components.

Altitude, to some extent, may influence the quality and quantity of the active medicinal components in plants. Studies suggest that the concentration of these active components is higher in some Himalayan plants growing naturally in higher elevations, when compared to those representing low altitude populations, such as *Aconite sp*. (Bahuguna *et al*. 2000). Similarly in the Himalayan Mayapple (*P. hexandrum*), known for its use in anticancer drugs, a higher medicinal content is reported for plants growing at higher altitudes (Purohit *et al*. 1999). However, some low elevation populations also had high levels of the active components which would indicate that altitude alone is not fully responsible for such variations. Natural environments too have influence over the active ingredients' availability in medicinal plants. A higher concentration of the active ingredients, demmarane saponins (or ginsenosides) has been clinically reported in wild Ginseng (Cottrell *et al*. 1996) when compared to cultivated varieties. In high altitude Himalayan Rhubarbs (*Rheum emodi* and *R. nobile*), active constituents decreased marginally when the plants were grown at lower altitudes (Prasad and Purohit 2001). In addition, seasons also influence the degree of availability of different active contents in Himalayan medicinal plants (Bahuguna et al. 2000. The understanding of climate dependent adaptive mechanisms is crucial to the development of the ex-situ cultivation programme of medicinal plant conservation initiatives (Badola and Pal 2002).

Phenotypic plasticity explains the adaptation advantage of specific characters to the immediate plant environment. The plant morphology of some high altitude medicinal plants may show marked variations among different populations. For example, leaf polymorphism and variation in leaf number is commonly seen in *P. hexandrum*. Narrow and broad leaf variants of *P. kurrooa*, a high altitude, endangered, and highly traded medicinal plant from Himalaya, show variations in active ingredient levels, the broad leaf variety appearing to be the most beneficial medicinally (Nautiyal *et al*. 2001). This species has recently been prioritized for immediate action in the ex-situ cultivation conservation program of endangered medicinal plants in HP (Badola and Pal 2003). In terms of habitat selection, the narrow leaf variant commonly grows in open pastures and along springs whereas the broad leaf variant is often found in habitats under shrub and scrub canopies. Similar experiences have been gained with a few Himalayan Aconites. This indicates the importance of morphological and genetic traits in identifying superior germplasm in the pursuit of either in-situ or ex-situ conservation (Badola 2002).

Figure 18. *Rhododendron arboreum* (Burans) flowers being sold by local children in HP

ANTHROPOGENIC INFLUENCES

Most of the species extinctions before the start of the 20th century took place as a gradual process over hundreds and even millions of years. However, a rapid global loss of species during the past century, particularly over the last five decades is an unprecedented phenomenon caused principally by extensive human interference in nature. The collecting of medicinal plants from nature for domestic use or in trade has been a common practice for centuries. For HP, about 66% of these taxa are used ethnomedicinally and 50% have commercial value. To meet the increasing demand of pharmaceutical companies in recent years, Himalayan medicinal plants have been harvested from the wild in an unsustainable manner. This has compounded the threat of population destruction, consequent habitat fragmentation, and species endangerment. Native villagers in Himachal Pradesh are legally allowed to harvest medicinal herbs from the designated forest lands as a traditional right under state forest law. Often this is an important source of village income through many parts of the Himalayas (see Figure 18). Due to growing competition among collectors, it is common practice to conduct early in-situ harvesting often when the plants are at an immature reproductive stage. This results in not only the insufficient collection of raw material but also in larger habitat area destruction and a situation where the natural regeneration of the plants is adversely affected. A population structure of species should provide not only their natural relationship with habitats but also indicate the trend of loss of individuals

Figure 17. A tree-line pasture of West Himalaya under anthropogenic degradation.

in degraded areas due to anthropogenic factors, when compared with relatively conserved sites. For Himalayan medicinal plants, such studies are few and localised (Airi *et al*. 2000, Uniyal *et al*. 2002); however, they remain a useful tool to indicate the trend in species conservation.

Species Endangerment and High Priority Taxa

Understanding the nature of the threats to the survival of species is necessary in developing management strategies for their conservation. For this purpose, the assessment of taxa using quantitative parameters, ranging from population structures to distribution data are vitally necessary. The IUCN definition for an endangered taxon is *"...when it is not 'Critically Endangered' but is facing a very high risk of extinction in the wild in the near future*". All taxa listed as Critically Endangered qualify for Vulnerable and Endangered, and all listed as Endangered qualify for Vulnerable; while the term "threatened" is used cumulatively for these categories (Hilton-Taylor 2000).

The principal reason for species endangerment in Himalayan medicinal plants is the human intervention in natural ecosystems, resulting in habitat destruction, as well as a host of other natural and biological factors. The use of wild plant resources and the subsequent ecosystem alteration often leads to habitat fragmentation. This results in species susceptible to slack habitat niches and a decline in genetic variability. Fragmented habitats are more fragile and have more difficulty sustaining populations, (especially small and narrowly distributed ones), and consequently this often leads to species endangerment. Habitat loss and degradation have been identified as the major factors, threatening 91% of plant species globally. In the 2000 IUCN red list, India is ranked sixth for having the highest number of threatened plant species. In the Red Data Book of Indian Plants (Botanical Survey of India (BSI)), out of a list of 620 threatened species, 550 are endemic in nature. However, 62 endemic and 209 near endemic (geographical distribution extends to adjacent areas) medicinal plant species are noted for the Indian Himalaya (Samant *et al*. 1998). The majority of endemic taxa with small geographical distributions are destined to be rare and prone to being threatened and consequently in want of habitat conservation. The rare species are highly vulnerable to extinction, and the future loss of biological diversity may be delayed or reduced if we better understand the mechanisms that account for their rarity. For Indian Himalaya, some important threatened medicinal endemic plants include, *Aconitum ferox* (Sikkim Himalaya), *A. deinorrhizum* (Himalaya), *A. falconeri* (H.P.), *Angelica glauca* (Indian Himalaya), *A. nubigena* (Sikkim), *Coptis teeta* and *Panax pseudo-ginseng* (eastern Himalaya), *P. kurrooa* (Himalaya), and *Podophyllum emodii* var. *axillaris* (Sikkim). Considerable depletion of these taxa has occurred mainly due to unsustainable exploitation from the wild for domestic and international trade. A recent study (Badola and Pal 2003) assessed 133 medicinal plants, (belonging to 59 families), of HP referred to as rare, sensitive, threatened and/or endangered for the state and/or other parts of the Himalaya. A broad range of conservation threats were noted. These 133 taxa include over 53% nativity to Himalayan region and 33.93 % endemism (IHR). Three families (Apiaceae, Asteraceae and Rannunculaceae) are under the highest threat category for having ten threatened high value medicinal plant taxa per family, e.g. *Angelica glauca, Centella asiatica, Inula racemosa, Jurinea dolomiaea,* and *Saussurea costus.* Table 1 provides a list of some important medicinal plants, considered threatened for the Himalaya in general, or locally for different regions of the Himalaya. This includes endemic taxa of high conservation concern such as *Aconitum ferox, Angelica glauca, Codonopsis affinis, I. racemosa* and *Saussurea bracteata* particularly due to their high altitude habitats. Sixty nine per cent of these total threatened taxa have a suitable habitat niche from 3000-4000 m (see Fig. 9).

More studies are required for assessing these Himalayan species for the exact nature of their endangerment, morpho-ecological behaviour, adaptive biology and the development of effective agro-technology. There may be several factors responsible for the endangerment of a species. Brown *et al.* (1984) defined 63 factors. Understanding the diversity of endangerment factors indicates the complexity of the required conservation efforts. Unfortunately, to date, except for a few attempts (Dhar *et al.* 2000) there are hardly any comprehensive analyses available covering the entire Himalayan region under a matrix, projecting the diversity of endangerment factors for medicinal plants.

Conservation Initiatives

The implementation of plant species conservation involves two broad approaches; (i) in-situ, the protection of species within habitats where the protected area networks play a crucial role and (ii) ex-situ, the use of botanical gardens, arboreta, and in-vitro methods including high-tech cryopreservation. Ex-situ cultivation of threatened plant taxa, particularly those in high demand for trade, has been seen as a practical step, not only in-directly supporting in-situ conservation (by diverting attention from in-situ harvesting) but also in reaching a sustainable supply of raw material.

The Endangered Species Act of 1973 (USA), widely regarded as the strongest law ever devised for species preservation by any nation (see: Flather *et al*., 1994) can be used as a model for species by species conservation. In many countries the regulatory controls on the wild harvesting of endangered medicinal plants have not proven effective due to numerous complications. In the

Plant Name	Family	Habitat	Part in Use	Trade prevention	Endemic status to IHR
Aconitum ferox Wall ex Seringe*	Ranunculaceae	Forest, shrubberies, grassy slope	Plant	Nexp	Endemic
Aconitum heterophyllum Wall. ex Royle*	Ranunculaceae	Forest, shrubberies, steep grassy slope	Root	Nexp	Near endemic
Acorus calamus L.	Araceae	Marshy meadow, riverine, wet-wasteland	Rhizome	Nexp	-
Angelica glauca Edgew*	Apiaceae	Forest, shady slopes, along springs	Root	-	Endemic
Arnebia benthamii I. M. johnstone*	Boraginaceae	Alpine shrubberies, open slope, pasture	Root	-	Near endemic
Atropa acuminata Royle.	Solanaceae	Forest, wasteland	Leaf, root	-	-
Berberis aristata DC	Berberidaceae	Shrubberies, open slope	Stem, bark, wood, root	Nexp	Near endemic
Cinnamomum tamala (Buch-Ham,) Nees.*	Lauraceae	Forest	Leaf, bark	-	Near endemic
Codonopsis affinis Hk. f. & Th.*	Campanulaceae	Shrubberies	Root	-	Endemic
Dactylorhiza hatagirea (Don) Soo*	Orchidaceae	Open slope, grassy slope, marshy meadow	Root (tubers)	Nexp	Near endemic
Ephedra gerardiana Wall. ex Stapf.	Ephedraceae	Riverine, dry rocky slope, disturbed habitats	Leaf, stem, fruit, root	Nexp	-
Gentiana kurroo Royle*	Gentianaceae	Shrubberies, gaps within scrub	Plant	Nexp	Near endemic
Gloriosa superba L.	Liliaceae	Forest	Rhizome	Nexp	-
Hedychium spicatum Smith*	Zingiberaceae	Forest, shrubberies, moist-shady place, grassy open pastures, moss laden rock	Rhizome	-	Near endemic
Inula racemosa Hook. f.*	Asteraceae	Cultivated areas	Flower, root	-	Endemic
Jurinea dolomiaea Boiss*	Asteraceae	Open slope, alpine pasture	Root	-	Near endemic
Meconopsis aculeata Royle.*	Papaveraceae	Open-slope, rock crevices, rotten logs, alpine pasture	Root	-	Near endemic
Nardostachys jatamansi DC.*	Valerianaceae	Rocky slope, grassy open slope	Root	Nexp, CII	-
Picrorhiza kurrooa Benth*	Scrophulariaceae	Moist rocky slope, rocky slope	Root	Nexp, CII	-
Podophyllum hexandrum Royle*	Berberidaceae	Forest, open slope, moist rocky slope, moss-laden rock	Fruit, root (rhizome)	Nexp, CII	-
Rauwolfia serpentina Benth. ex Kurz.	Apocynaceae	Forest	Root	Nexp, CII	-
Rheum australe D. Don*	Polygonaceae	Open slope, alpine pasture	Rhizome	Nexp	Near endemic
Rhododendron anthopogon D. Don*	Ericaceae	Shrubberies, alpine pasture, open slope	Leaf	Nexp	Near endemic
Rhododendron campanulatum D. Don*	Ericaceae	Forest, shrubberies, forest fringe	Leaf, flower, root	Nexp	Near endemic
Saussurea bracteata Decne*	Asteraceae	Open slope	Plant	-	Endemic
Saussurea costus (Falc) Lipsch.*	Asteraceae	Rocky pastures, cultivated areas	Root	Nexp, CII	-
Selinum tenuifolium Wall. ex C.B. Clarke*	Apiaceae	Open slope, grassy open slope, rock crevices, forest fringe	Root	-	Near endemic
Swertia chirata (Roxb. ex Flem.) Kars.*	Gentianaceae	Forest, moist places	Plant	Nexp	Near endemic
Taxus baccata L. subsp. *wallichiana* (Zucc.) Pilger	Taxaceae	Mixed forest, ravine	Leaf, bark	Nexp, CII	-
Valeriana jatamansi Jones*	Valerianaceae	Open slope, moist rocky slope, rock crevices, cultivated areas	Rhizome	-	-

Table 1.

Indian Himalaya, various state forest departments govern the regulation of extraction, marketing and export of medicinal herbs and maintain lists of plants for issuing appropriate licenses to harvesters and exporters. Several of these taxa iave been mentioned in the negative list of export from India, viz., *Aconitum heterophyllum* (Aconite or Patish), *Acorus calamus* (Bach), *Berberis sp.*, *Dactylorhiza hatagirea* (Panja), *Dioscorea deltoidea* (Singli-mingli), *Picrorhiza kurrooa* (Karu), *Podophyllum hexandrum* (Bankakri), *Saussurea costus* (Kuth) and *Taxus baccata* (Rikhar). It is important to note that there is a vibrant trade network that openly ignores these regulations, an open fact throughout the entire Himalaya. Trans-border illegal exports between Himalayan countries are known, including those of *Nardostachys grandiflora* and *P. kurrooa* from Nepal to India (Mulliken 2000).

In India, there are over 75 national parks and 421 wildlife sanctuaries, representing over 4.2 % of the nation's geographical area. These are targeted to support in-situ conservation of species, particularly those with threatened status. In Himalaya, protected area networking is relatively moderate. Nayar (1996) listed 25 protected areas in north-east states, 5 in Sikkim-Darjeeling, 9 in Uttaranchal and 19 in Jammu & Kashmir. Currently, Himachal Pradesh has 2 national parks and 32 wildlife sanctuaries. In recent years, management of several of these protected areas have identified medicinal plants as one of the top conservation priorities. Attempts have been made to implement in-situ as well as ex-situ management strategies. Since a species needs specific habitat requirements in order to survive, emphasis has been given to the protection of ecosystems, the maintenance of viable populations, and the management of natural habitats. The prioritization of threatened taxa for immediate action as well as for long term planning has a high bearing on the success of any management planning and conservation initiative. Various forums have taken up the prioritization of taxa in recent years, however the results have been limited due to the wide array of geographical and local climatic conditions in Himalaya Research is required on many levels, from the collection of data on habitat based populations, regional and local distribution patterns, in-situ harvesting pressure and the conservation perception of the local people regarding the targeted taxa to assess the endangered status. Thenecessity of attempting more assessments to prioritize medicinal plant species covering different agro-climatic zones in the Himalayan regions is indicated in recent studies and experts' group exercises (see; Dhar *et al*., 2000; Badola and Pal, 2002). Table 1 includes species such as; *Aconitum heterophyllum* (vulnerable), *Codonopsis affinis* (rare), *Dioscorea deltoidea* (vulnerable), *Inula racemosa* (vulnerable), *Nardostachys grandiflora* (vulnerable), *Picrorhiza kurrooa* (vulnerable) and *Saussurea costus* (endangered), which are included in the Red Data Book of Indian Plants. Recently, 14 endangered Himalayan medicinal plants were assessed in an expert's group exercise and prioritized for conservation through ex-situ cultivation in four agro-climatic zones of HP (Badola and Pal, 2002). Figure 19 illustrates the availability of some of these prioritized taxa in different districts of the Himachal state. This exercise ranked *Nardostachys grandiflora* (Jatamansi; listed in Indian Red Data; in Appendix II of CITES) and *Swertia chirata* (Chirayita; sensitive, Dhar *et al*., 2000) as the top level endangered taxa for their respective agro-climatic zones in HP *Dactylorhiza hatagirea* (Panja), the second ranked taxon for the cold-desert zone in the above exercise, was noted as critically endangered for HP, adopting IUCN criteria (Ved and Tandon, 1998). In an immediate action for ex-situ cultivation, the experts prioritized *Picrorhiza kurrooa* (Karu). As a signatory to the Convention on Biodiversity, the Government of India is legislating to restrain the over-exploitation of endangered medicinal plants in the wild. Recent Government policies such as the much debated Biodiversity Bill, National Policy and Macrolevel Action Strategy on Biodiversity (1999) and the National Agriculture Policy (1999) have been encouraging. Recently a Bioresource Board along with a Medicinal Plant Board were established in the Central Government. Very recently, different state governments in the Indian Himalaya have set up biotechnology departments to deal with the conservation and sustainable use of medicinal plant resources. Many organizations in Himalaya have recently taken up medicinal plant conservation as one of the priorities on their agenda. These initiatives, though laudable, will be severely limited if comprehensive and long term field studies are not conducted. A collaborative, multiple expertise, scientific approach is required for these efforts to be successful. Limited and insufficient agro-technology and field trials lead to confusion among farmers and forest area managers. Better synchronization between the scientific community and the natural area mangers is vital for effective conservation action in the wild. Furthermore, the long-term conservation mission for medicinal plants, particularly threatened taxa in Himalaya, requires the participation of the native community for a successful, sustainable approach. There is an urgent need for cooperation among national and international

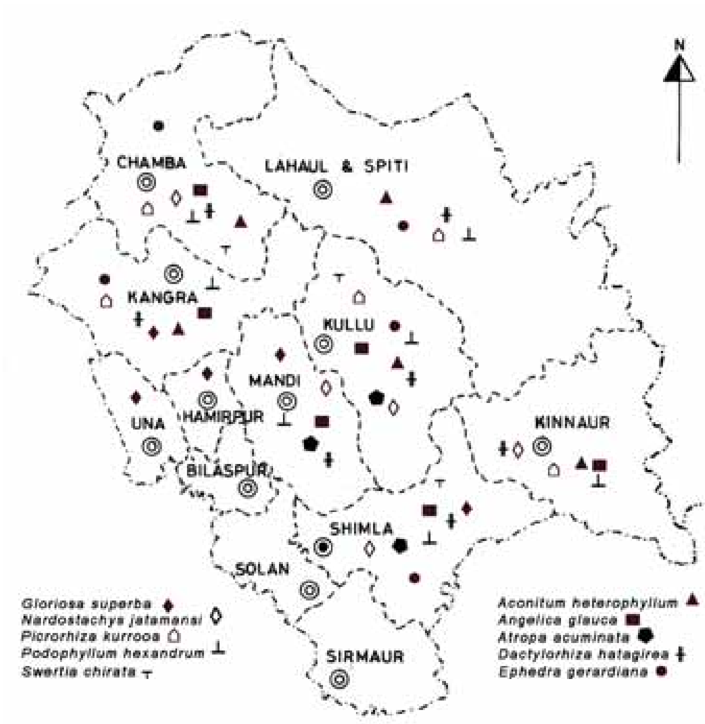


Figure 19. Map of Himachal Pradesh showing district level availability of some top threatened Himalayan medicinal plant species. (H.K. Badola & S. Aitken).

organizations to create reliable and realistically viable conservation initiatives for medicinal plants in Himalaya (Badola and Pal 2002, Dhar *et al.* 2002).

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